Impact of assimilation of ASCAT winds in NCMRWF GDAF system

Anjari Gupta*, S. Indira Rani and V.S.Prasad
National Center for Medium Range Weather Forecasting (NCMRWF)
Ministry of Earth Sciences (MoES)
Noida (U.P)
*Email: anjari@ncmrwf.gov.in

ABSTRACT

The impact of Advanced Scatterometer (ASCAT) winds in National Centre for Medium Range Weather Forecasting (NCMRWF) Global Data Assimilation and Forecasting System (GDAFS) has been estimated in this study. The assimilation technique used is the Grid Statistical Interpolation (GSI) scheme, a version of three dimensional variational methods in the NCMRWF T574L64 model. Model has been run without (EXP) and with (CNTL) ASCAT winds along with other conventional and satellite observations routinely assimilating in NCMRWF T574L64 model. The model has been run for a period of 18 days spanning from 6 to 23 June 2011, during this period two depressions were formed over the Indian Ocean. Positive impact in the analysis and forecast fields were observed, especially in the fields like vorticity, relative humidity and low level wind due to the assimilation of ASCAT winds.

1. Introduction

Deterministic numerical weather prediction (NWP) has steadily improved during the past several decades. Many factors have contributed to the noted improvement including advanced data assimilation algorithms, new observing systems, improved modeling techniques and advancements in computing powers allowing for higher spatial resolution. Ocean surface winds derived from scatterometer, on-board polar orbiting satellites, are one of the crucial observations over data sparse Oceanic region. In this regard, EUMETSAT's Advanced Scatterometer (ASCAT) surface winds are routinely being assimilated in NCMRWF Global Data Assimilation and Forecast System (GDAFS). In this study, an attempt has been done to estimate the impact of ASCAT surface winds in the NCMRWF GDAFS during two depressions over the Indian Ocean during June 2011. A brief discussion of the NCMRWF data assimilation system and ASCAT data are given in Section 2 and 3 respectively. Section 4 narrates the design of the experimental set up and the results are discussed in Section 5. The main findings from the study are concluded in Section 6.

2. NCMRWF GDAS

The Global Data Assimilation System (GDAS) operational at NCMRWF is a six hourly intermittent three dimensional scheme. Meteorological observations from all over the globe and from various conventional and remote sensing observing platforms are received at Regional Telecommunication Hub (RTH), New Delhi through Global Telecommunication System (GTS) and the same is made available to NCMRWF. Global analysis is generated four times a day at 0000, 0600, 1200, and 1800 UTC. Meteorological observations from various types of observing platforms assimilated in T574L64 (~ 23 km horizontal resolution) global analysis scheme at NCMRWF are SYNOP, BUOY, METAR, TEMP, PILOT, AIREP, AMDAR, ACARS, Atmospheric Motion Vectors (AMVs) from geostationary satellites, viz. GOES, METEOSAT and GMS, NOAA and METOP satellite radiances, Global Positioning System Radio Occultation (GPSRO) observation, etc . A six hour prediction from model with a previous initial condition valid for current analysis time is used as the background field or first guess field for subsequent analysis. The global analysis scheme used is Grid point Statistical Interpolation (GSI). The key aspect of GSI is that it formulates the analysis in model grid space, which allows for more flexibility in the application of the background error covariance and makes it straight forward for a single analysis system to be used across a broad range of applications, including both global and regional modeling systems and domains. The implementation details of the new GFS system as well as preliminary results are detailed in Prasad et al., (2011a and b) available on http://www.ncmrwf.gov.in/Reports.

3. ASCAT data

The ASCAT was launched by EUMETSAT on-board MetOp satellite on 19th October 2006. The

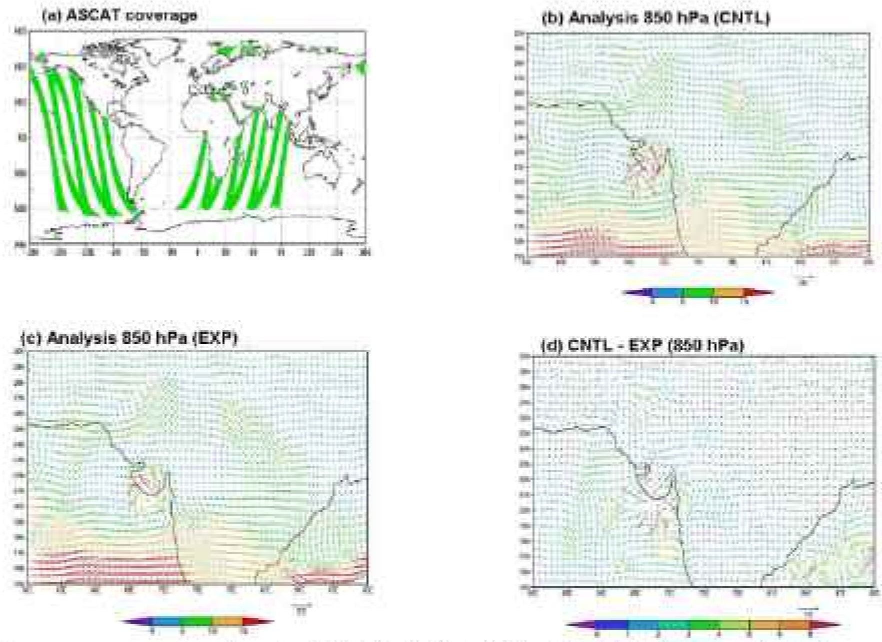

Fig.1 (a) ASCAT data coverage received at NCMRWF within the 06 UTC assimilation cycle of 12 June 2011 (b) 850 hPa Analysis winds from CNTL run (c) 850 hPa analysis wind from EXP run and (d) the difference between CNTL and EXP for 12 June 2011

scientific and technical documentation related to ASCAT derived products can be found at the website http://www.knmi.nl/scatterometer/publications/. MetOp is in a circular orbit for a period of about 101 minutes, at an inclination of 98.59° and at a height of 800 km with a 29-day repeativity. ASCAT has two swaths 550 km wide, located each side of the satellite track, separated by 700 km. It operates at 5.3 GHz (C band). Its fore-beam and aft-beam antennas point at 45° and 135° on each side of satellite track. The mid-beam antenna points at 90°. The ASCAT beams measure normalized radar cross sections with vertical polarization (σ_0), which are dimensionless property of the surface, describing the ratio of the effective echoing area per unit area illuminated. The fore and aft-beams provide backscatter coefficient measurements at incidence angle varying between 34° and 64°. The mid-beams provide σ_0 measurements at incidence angle varying between 25° and 53°. Backscatter coefficients are provided with two spatial resolutions of 25 km and 12.5 km over the global ocean. Recent study by Li et al. (2011) shows significant improvement, after addition of ASCAT data in NCEP GDAS, in forecast from day 4 through day 7.

4. Design of Experiment

NCMRWF is routinely assimilating ASCAT winds in T574L64 global model operationally. Two depressions were formed over the Indian Ocean during June 2011, each over the Arabian Sea during 11 – 12 June 2011 and Bay of Bengal during 16 – 23 June 2011. In this study, the routine NCMRWF operational runs are considered as control run (CNTL) and the model runs without ASCAT winds during the same period are considered as the experimental run (EXP). Model analysis and 7day forecasts in CNTL and EXP cases from 06 to 23 June 2011 frame the backbone of this study. Both the depression cases are analyzed and results are discussed in detail.

5. Results and Discussion

5.1 Impact of ASCAT wind data assimilation in the Analysis

5.1.1 Depression of 11-12 June 2011

In early June, a low pressure area was formed over the Arabian Sea. On June 11, India Meteorological Department (IMD) upgraded the area of low pressure to a depression. At that time, it was located approximately 180 km northwest of Mumbai and 150 km southeast of Veraval, Gujarat, India. Later, on June 12, IMD reported that depression had crossed Saurashtra coast of India about 25 km east of Diu. Later, on the same day, IMD reported that depression had weakened into a well marked low pressure area. Figure 1(a) shows the ASCAT data coverage received at NCMRWF on 06 UTC of 12 June 2011. Figure 1(b) and (c) are the model analysis wind at 850hPa in CNTL and EXP runs respectively for 12th June 2011.

The circulation and intensity of depression over the coast of Saurashtra is intense in the CNTL run (Figure 1b) compared to the same in the EXP run (Figure 1c). Figure 1a is the difference between the 850 hPa analysis wind in the CNTL and EXP. It is noted that the difference in wind speed is upto 8-10 m/s over the depression area. This difference is attributed due to assimilation of ASCAT winds in the CNTL.

Wind shear and vorticity, which determine the storm circulation feature, are analysed for the in depth understanding of the depression in both CNTL and EXP runs. Analysed vertical wind shear and low level vorticity in CNTL and EXP runs for 12 June 2011 are shown in Figure 2. The top panel is the vertical wind shear and the bottom panel is the absolute vorticity at 850 hPa in the CNTL and EXP run valid for 06 UTC of 12 June 2011. Figure 2 shows lower wind shear in CNTL (Figure 2a) run compared to EXP (Figure 2b) run. Lower wind shear is needed for storm's circulation, which is seen in CNTL run. Also, the vertical vorticity is more and well defined structure is seen in CNTL (Figure 2c) run as compared to EXP (Figure 2d) run. These factors contribute towards better structure of depression in CNTL run (Figure 1b).

T574L64 model Analysis of 850hPa relative humidity in CNTL and EXP runs for 12 June 2011 is shown in Figure 3. It is seen that low level relative humidity is more in CNTL (Figure 3a) run over the Gujarat coast as compared to EXP (Figure 3b) run.

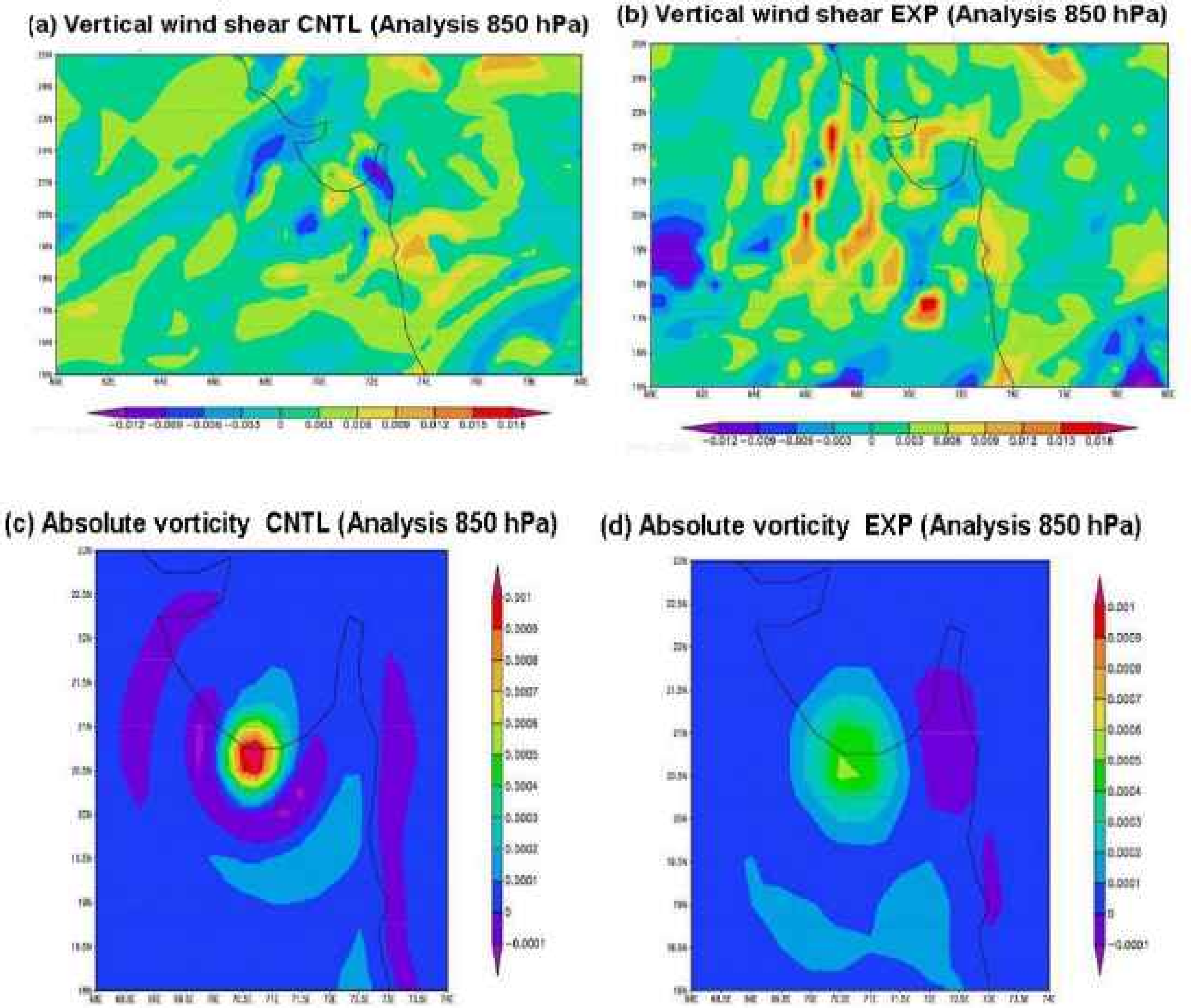

Fig.2 T574L64 model analysis vertical wind shear (a) CNTL and (b) EXP and low level absolute vorticity (c) CNTL and (d) EXP at 850 hPa for 12 June 2011.

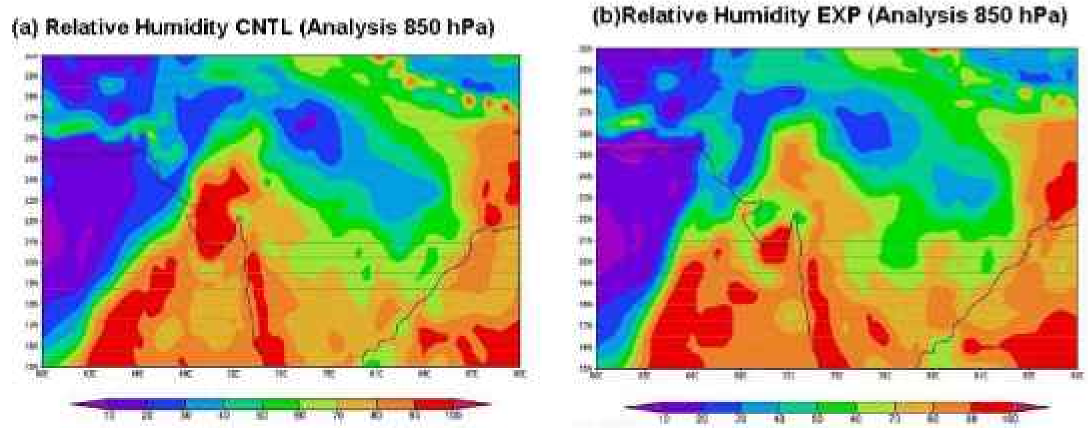

Fig.3 T574L64 model analysis relative humidity at 850hPa (a) CNTL and (b) EXP valid for 12 June 2011

High humidity in low level certainly adds to the better formation of cyclonic system over the ocean surface.

5.1.2 Depression of 16-23 June 2011

A deep depression was formed over north Bay of Bengal on 16th June 2011. While moving northwards, it crossed West Bengal-Bangladesh coast, about 100 km east of Sagar Island between 1100 and 1200 UTC of 16 June 2011. It then continued northward movement for some time, then moved west-north westwards across Gangetic West Bengal, Jharkhand, north Chhattisgarh and west Madhya Pradesh during 17-23 June 2011 and weakened gradually. It weakened into a well marked low pressure area on 23 June 2011 over west Madhya Pradesh. It ushered southwest monsoon over eastern and central India and caused excess rainfall over these regions. Figure 4 shows model analysis wind at 850hPa for 17 June in CNTL (Figure 4a) and EXP (Figure 4b) runs and the difference between two. CNTL run shows better wind circulation over the depression area. This difference is because of additional data going into model assimilation cycle and improved atmospheric fields due to continuous assimilation since 06 June 2011. The difference plot (Figure 4c) shows that difference is of the order of 5-8m/s over the depression area.

Low level relative humidity in CNTL and EXP runs on 17 June 2011 is shown in Figure 5. It is noted from Figure 5 that there is not much difference in low level relative humidity between CNTL (Figure 5a) and EXP (Figure 5b) runs. Thus it is confirmed that the difference in the low level

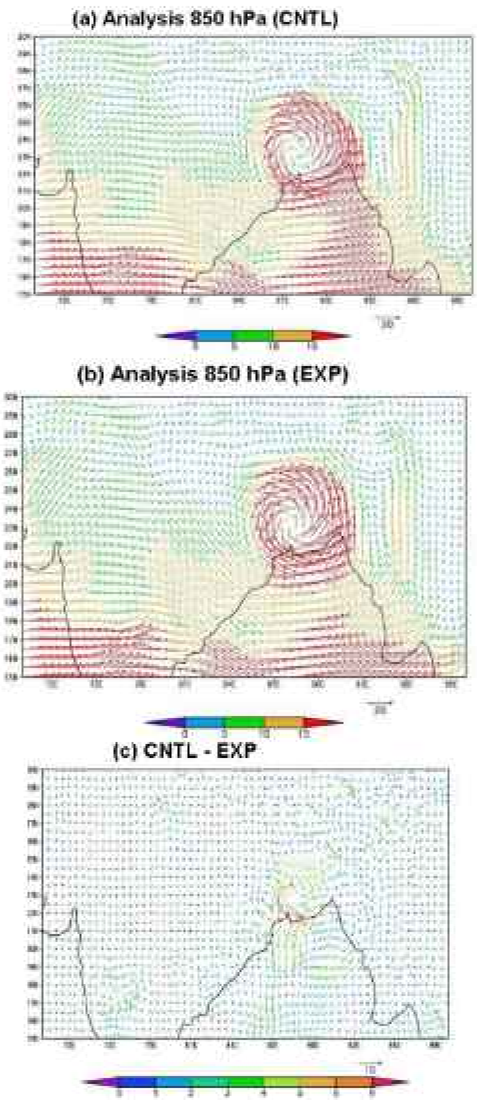

Fig.4 T574L64 model analysis wind at 850 hPa (a) CNTL, (b) EXP and (c) the difference between CNTL and EXP run valid for 17 June 2011

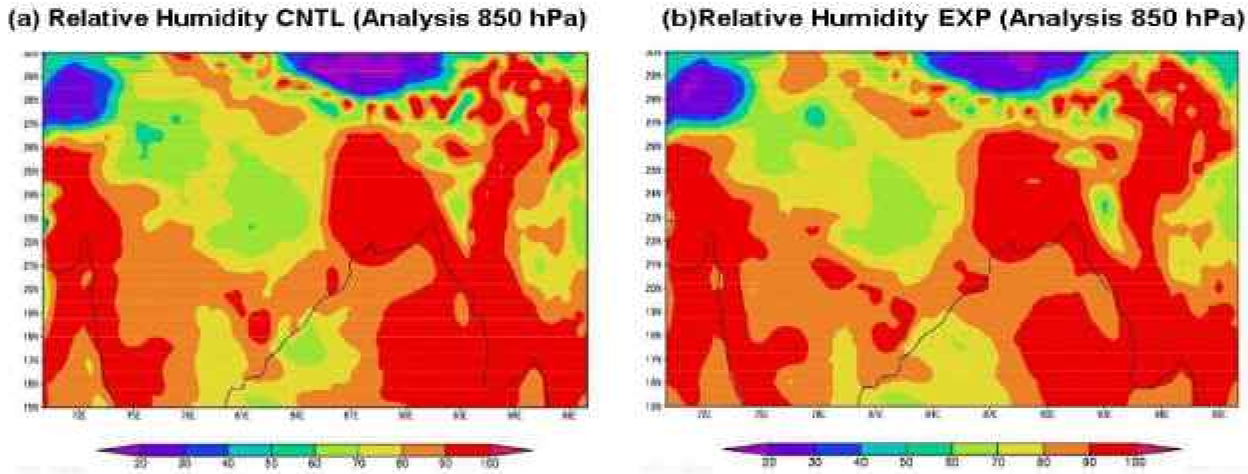

Fig. 5 T574L64 model analysis relative humidity at 850hPa (a) CNTL and (b) EXP valid for 17 June 2011

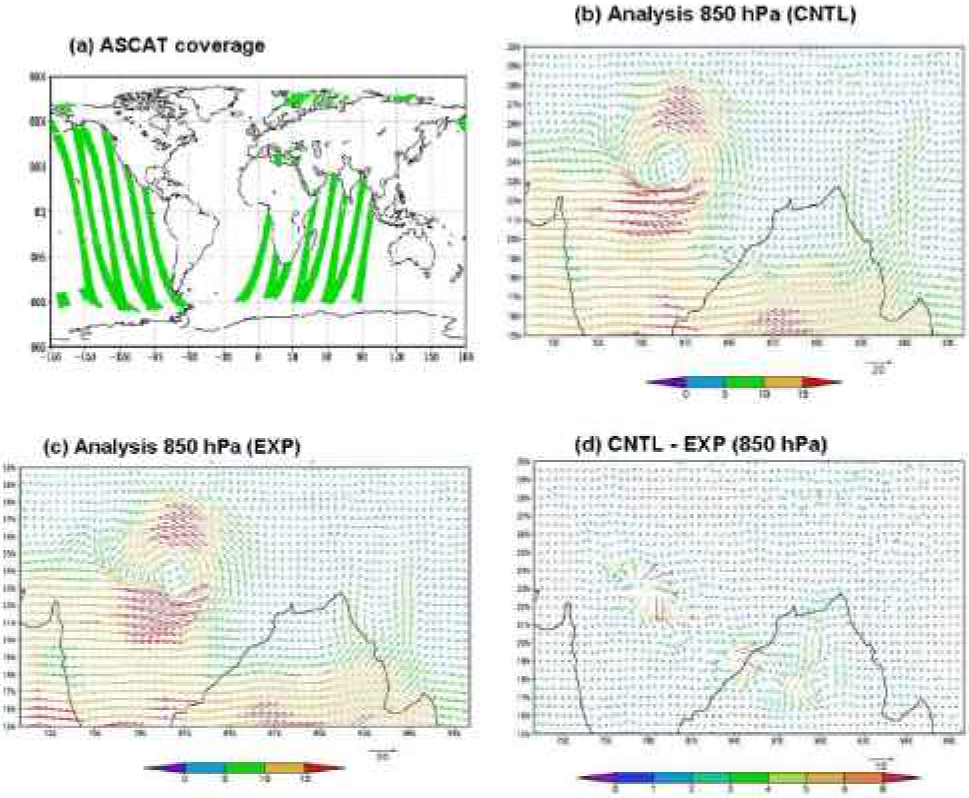

Fig.6 (a) ASCAT data coverage received at NCMRWF within the 06 UTC assimilation cycle of 22 June 2011 (b) 850 hPa Analysis winds from CNTL run (c) 850 hPa analysis wind from EXP run and (d) the difference between CNTL and EXP for 22 June 2011

wind circulation seen in Figure 4c is mainly due to improvement in atmospheric fields due to continuous data assimilation of ASCAT winds since 6 June 2011.

Figure 6 is similar to Figure 1 but for 22 June 2011. The difference between the CNTL and EXP (Figure 6c) clearly shows the impact of ASCAT wind assimilation. A difference in wind speed of 5-8 m/s is noticed around depression area (Fig.6c).

5.1.3 Track position errors of two considered depressions in CNTL and EXP cases

Table 1 shows the track position errors of two depression cases CNTL and EXP runs. Position error is calculated with respect to IMD reported locations of two depressions. It is seen that error is more in CNTL (with ASAT) case for 12th

0000UTC and 19th June 1200UTC locations. Error is less in CNTL case for 11th, 18th and 20th Jun 2011 1200UTC locations.

5.2 Impact of ASCAT wind assimilation the model forecast of surface parameters

Difference in model analysis must make difference in model forecast. Figure 7 shows 24 hour forecast of 850hPa wind and rainfall valid for 00 UTC of 13 June 2011 in CNTL and EXP runs. Figure 7a and b are the 24 hour forecast of 850 hPa winds respectively from CNTL and EXP runs valid for 13 June 2011. Figure 7 c and d are the corresponding 24 hour forecast rainfall from CNTL and EXP runs. It is seen that CNTL run is showing better wind circulation pattern in 24 hour forecast as compared to EXP run, where the circulation is almost dissipated. Rainfall is also predicted more in CNTL run over the depression area as compared to EXP run.

Fig.8 shows the 24 hour rainfall forecast from CNTL and EXP run along with the IMD gridded rainfall for 22 June 2011. In EXP run (Figure 8b), rainfall is under predicted when compared with IMD observed rainfall (Figure 8c). In IMD observations, there is huge amount of rainfall over 22-26^{0} N,76-82^{0} E, which is of the order of >8-32cm. In CNTL

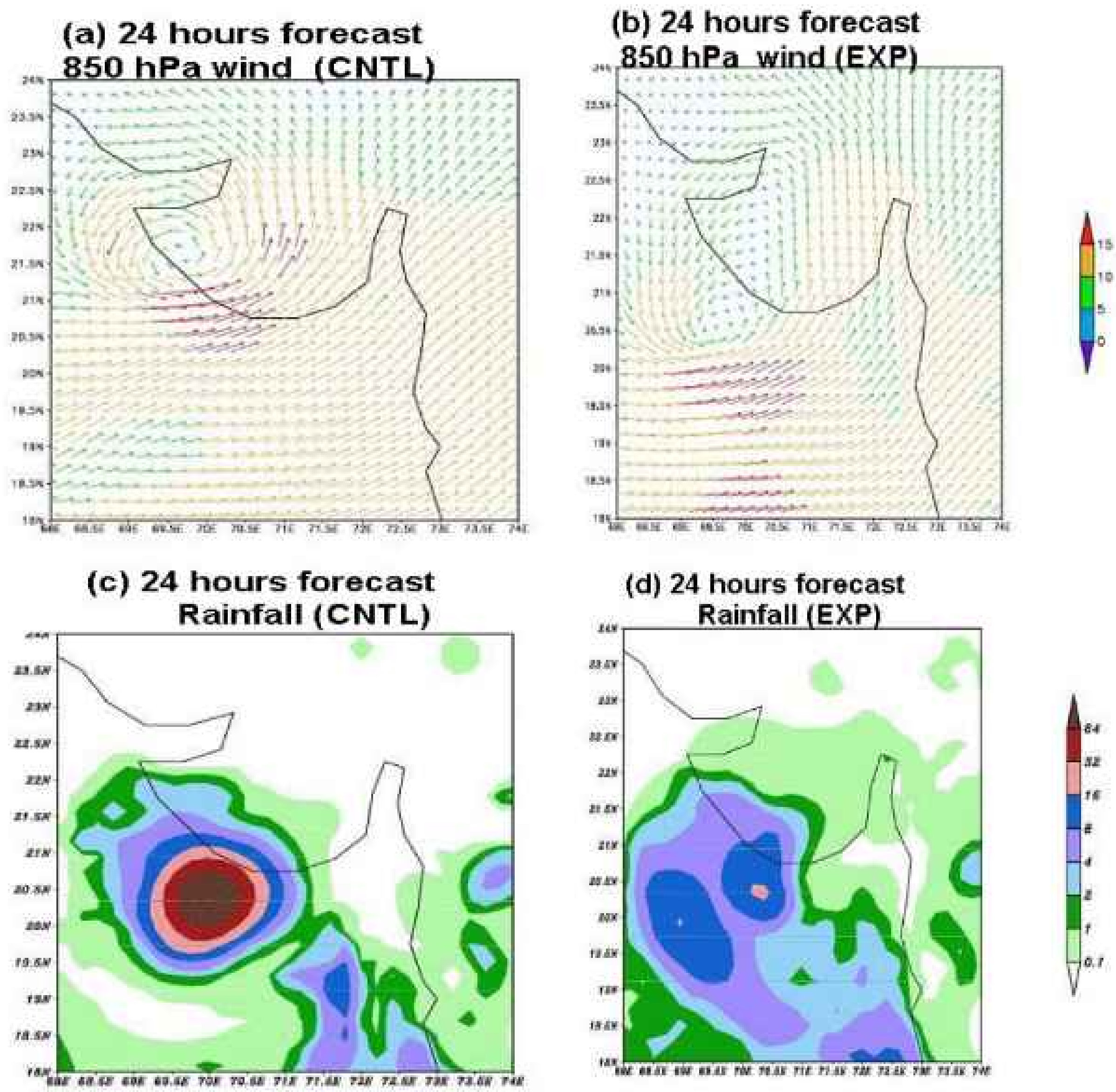

Fig.7 24hr forecast of 850 hPa wind (a) CNTL and (b) EXP and 24 hour rainfall (c) CNTL and (d) EXP valid for 13 June 2011 run (Figure 8a), more rainfall is predicted compared to EXP run, over 23-25^0 N, 84-86^0 E. Over this region, rainfall predicted in CNTL run is of the order of 16-32cm. Rainfall prediction is better in CNTL run when compared with IMD observations in terms of maxima predicted over West Madhya Pradesh and adjoining areas.

5.3 Verification Scores

Objective verification scores for both CNTL and EXP forecasts against the observations valid for 00UTC and also against their mean analyses at standard pressure levels as recommended by WMO are computed for the study period (06 June 2011 – 23 June 2011). NCEP verification system, which generates the Verification Statistics Data Base (VSDB) (Murphy, 1988), is used in the present study. This system helps in computing various statistical scores for determining quality of analysis with respect to the observations as well as quality of forecasts with respect to both analysis and observations. Complete model verification

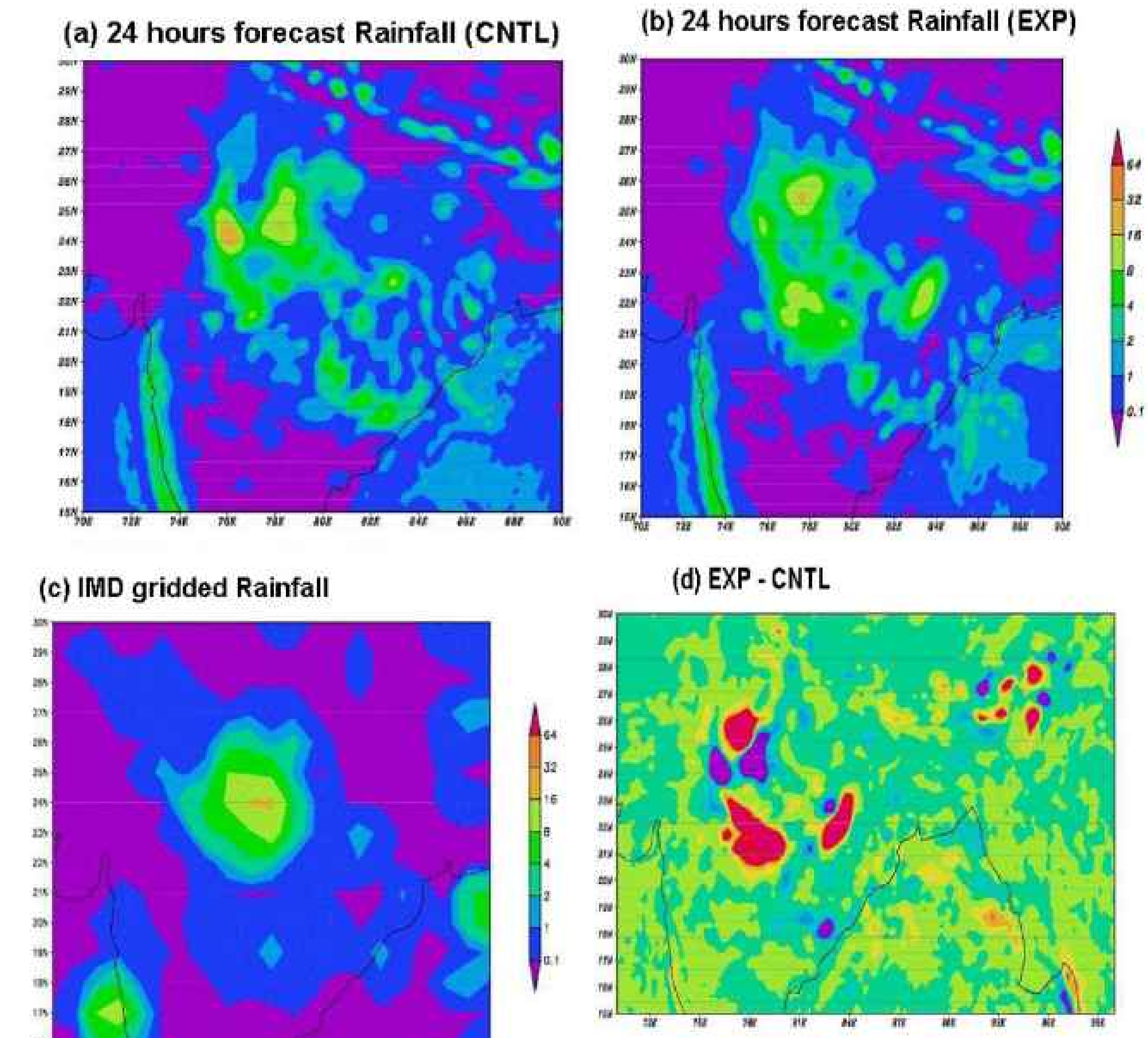

Fig.8 24 hour rainfall forecast from (a) CNTL and (b) EXP, (c) IMD gridded rainfall and (d) the difference between CNTL and EXP for 22 June 2011

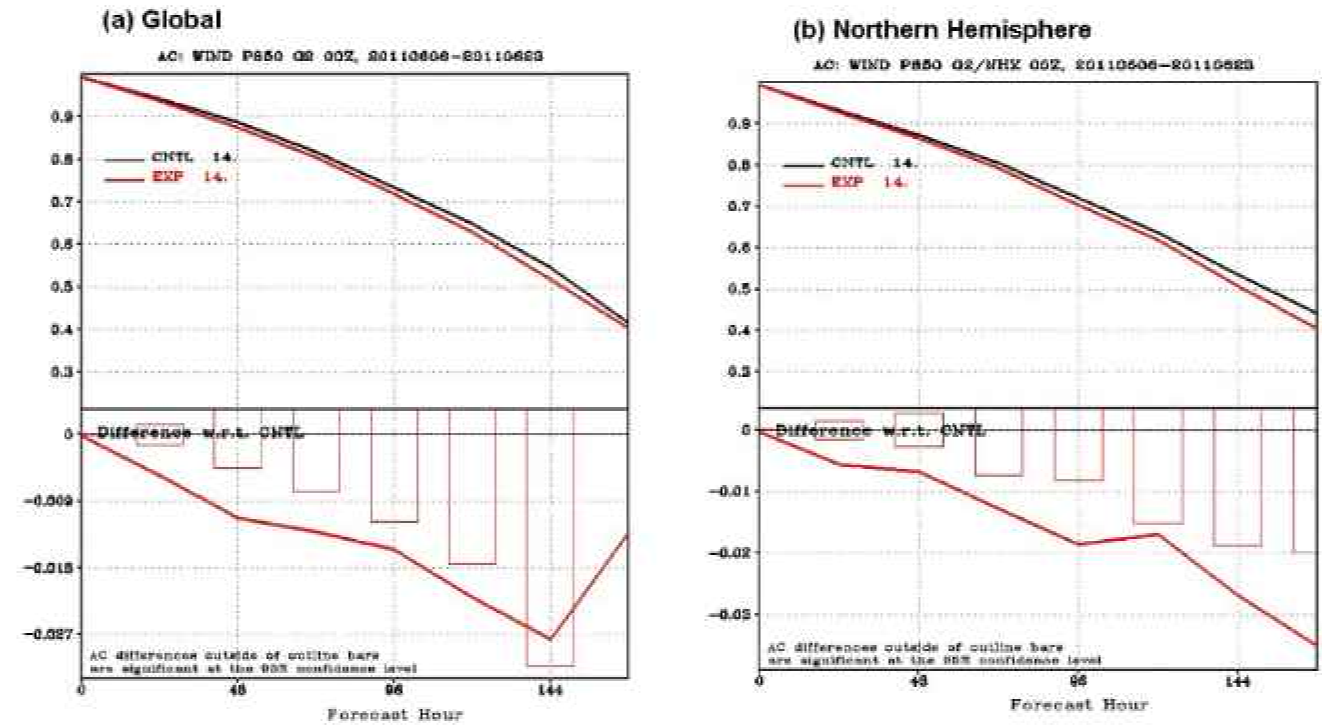

Fig.9 Anomaly Correlation over (a) Global and (b) Northern Hemisphere for day1 to day7 (upper part of the figures) and anomaly correlation difference of CNTL simulations with respect to EXP simulations along with their statistical significance (lower part of the figures) for WIND at 850hPa level

should include mean square error skill score, anomaly correlation, Error of mean difference and Error of Pattern Variation, Pattern correlation, Ratio of forecast variance to analysis variance. Some of the key results are discussed below. Five regions over the entire globe, viz. Global, Northern Hemisphere, Southern Hemisphere, Tropics (30°S to 30°N) and RSMC (10°S to 40°N, 40° to 100°E) are considered.

Improvement in analysis is followed by the improvement in forecast. For the impact over the forecast simulation, forecasts are first compared with the mean of the CNTL and EXP analysis. The scope of VSDB package in comparing two forecast systems is mention ed in Prasad et al., (2011b). Figure 9 shows anomaly correlation of 850hPa wind for day1-day7 forecast in Global and Northern Hemisphere regions. It can be seen from the figures that there is difference in anomaly correlation between CNTL and EXP runs for day 2 to day 6 forecasts in northern hemisphere and global regions. The Anomaly correlation differences outside the outline bars are significant at the 95 % confidence level. In the lower panel, the line plot depicts the difference of parameter simulated in CNTL run with respect to that simulated in EXP run. There is lead of few hours in CNTL run over EXP run simulations.

6. Conclusions

This study is focused on assessing the impact of assimilation of ASCAT surface winds in NCMRWF GDAFS. Improvements in the analysis and forecast fields are noticed with the assimilation of ASCAT winds. In both the depression cases analysed in this study, the assimilation of ASCAT winds improved the circulation pattern. Improvement in the model forecasted rainfall due to the assimilation of ASCAT winds is verified with respect to the IMD observed rainfall value. Track of 11-12 June depression is shown to have improved after addition of ASCAT data. 7day forecast was generated in both EXP and CNTL cases and was verified using NCEP VSDB statistics package. The anomaly correlation of 850hPa wind for all 7days of forecast is improved after addition of ASCAT data. Mean square error skill score is computed for day1, 3 and 5 forecast of 850hPa wind. It is shown that skill score of 850hPa wind improved with the assimilation of ASCAT winds.

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TABLE 1

Track position error in the CNTL and EXP runs with respect to IMD best track position for the two depression cases

Date/Time	IMD reported	Simulated in EXP run	Simulated in CNTL run	Position error in EXP run	Position error in CNTL run
11th Jun 2011 1200UTC	20°N, 7 l.6°E	19.8°N, 7 1.7 °E	20°N, 7 l.8°E	0.22	0.2
12th Jun 2011 OOOOUTC	21°N, 70.4°E	20.3°N, 70.9°E	20.5°N, 7 l.6°E	0.86	1.3
16th Jun 2011 1200UTC	2l.5°N, 89°E	22.2°N, 89.7°E	22.2°N, 89.8°E	0.99	1.06
11th Jun 2011 1200UTC	23°N, 88°E	22.9°N, 88.2°E	23.l 0N, 88.3 °E	0.22	0.32
18th Jun 2011 1200UTC	23°N, 87°E	23°N, 86.4°E	23.2°N, 87.2°E	0.6	0.28
19th Jun 2011 1200UTC	23.5°N, 85°E	23°N, 85.4°E	23.4 °N, 86.4°E	0.64	1.4
20th Jun 2011 1200UTC	24°N 83°E'	23.3°N, 84.2°E	24.2°N, 84.2°E	1.4	1.1
21st Jun 2011 1200UTC	24.5°N, 8 1°E	24.7°N, 80.8°E	24.7°N, 80.8°E	0.28	0.28

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References

Li, B., Jung, A. J., Morgan, M .C. and Le Marshall, J. F. 2011: Assessment of assimilating ASCAT surface wind retrievals in the NCEP Global Data Assimilation System. Monthly Weather Review, 139, 3405-3421.

Murphy, A. H. 1988: Skill scores based on the Mean Square Error and their relationships to the correlation coefficient. Monthly Weather Review, 116, 2417-2424.

Prasad, V.S., Mohandas, S., Das Gupta, M., Rajagopal, E. N., and Dutta, S. K. 2011(a): Implementation of upgraded Global Foreasting Systems (T382L64 and T574L64) at NCMRWF, NCMRWF Technical Report No. NCMR/TR/5/2011, National Centre for Medium Range Weather Forecasting, Min. of Earth Sciences, A50, Sector62, Noida, May 2011, pp72.

Prasad, V.S., Mohandas, S., Das Gupta, M., Rajagopal, E. N., and Dutta, S. K. 2011(b): Intercomparison of Medium Range Prediction of the Indian Summer Monsoon 2011 with T382L64 and T574L64 GFS. NCMRWF Research Report No. NMRF/RR/04/2011, National Centre for Medium Range Weather Forecasting, Min. of Earth Sciences, A50, Sector62, Noida, November 2011, p80.